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Identifying and Mitigating Industrial Base Risk for the DoD: Results of a Pilot Study

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14. ABSTRACT
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Panel 14. Trends and Risks in the Global Industrial Base

Thursday, May 15, 2014	
11:15 a.m. – 12:45 p.m.	**Chair: John Birkler,** Senior Fellow, Manager, Maritime Programs, RAND Corporation ***Defense Contracting Trends by Platform Portfolio*** David Berteau**,** Center for Strategic & International Studies Rhys McCormick, Center for Strategic & International Studies Gregory Sanders, Center for Strategic & International Studies ***The Case for the Development of a Theoretical Framework for Defence Acquisition*** Kevin Burgess, Cranfield University Thomas Ekström, The Swedish National Defence College ***Identifying and Mitigating Industrial Base Risk for the DoD: Results of a Pilot Study*** Sally Sleeper, OUSD(AT&L) Manufacturing and Industrial Base Policy Gene Warner, OUSD(AT&L) Manufacturing and Industrial Base Policy John Starns, Northrop Grumman Inc.

Identifying and Mitigating Industrial Base Risk for the DoD: Results of a Pilot Study

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Abstract

The DoD requires insight into the stress that reduced acquisition spending is placing on the industrial base. Implementing a reliable and validated methodology would facilitate DoD-wide mitigation actions designed to preserve or enhance key industrial base capabilities. The Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy has developed and tested a methodology for measuring the criticality of key capabilities (products, components, technologies) and their fragility within the industrial base (vendors and markets). The methodology is designed to be used across services and programs. Pilot testing conducted in 2013 of selected DoD programs and sectors applied this methodology to measure nine constructs of criticality and six constructs of fragility. The pilots assessed sectors and programs in diverse life-cycle phases, for example, development, production, and sustainment. Data collected from surveys, datasets, reports, and industry subject matter experts were used to assess the measures for capability/supplier pairs. Assessments were plotted in a fragility and criticality matrix to inform mitigation strategies. Empirical and statistical analyses indicate the methodology yields useful objective measures of risks in the industrial base. Results of the pilot tests were used for mitigation action and improved the methodology for future assessments.

Introduction

> The character of the defense industry has changed significantly. The large prime contractors and major subcontractors are no longer stand-alone organizations devoted primarily to defense business. The companies have become elements of large multi-product, multi-market organizations, and must compete internally for the limited capital that is available. … The decline in engineering and scientific graduates is well documented, but perhaps less visible in the current increasing shortage of skilled production workers, electronics technicians, tool and die makers. … The problems of the primes

> and large subcontractors are very often intensified in smaller subcontractors and suppliers. (Defense Science Board, 1981, pp. 7, 9, 18)

The findings from a Defense Science Board (DSB) Summer Study Panel on Industrial Responsiveness remains as relevant today as it was over 30 years ago. In 2008, the DSB Task Force on Defense Industrial Structure for Transformation concluded that the end of the Cold War once again had a significant impact on the U.S. industrial base due to drastic reductions in the defense budget. Their report echoed warnings about the health of companies that support the DoD, the lack of independent research, and loss of scientists and engineers in the defense industry, and urged the DoD to develop incentives to achieve "a balance between innovation that delivers superior capability and increased production quantities of existing designs" (DSB, 2008).

While the national security environment and issues are different in the two reports, they are consistent in their expression of concern that the industrial base may not be able to meet the future DoD needs in equipping and sustaining military forces. And in 2014, the concern remains as the Department must make important decisions about its investment priorities as the procurement budget is reduced by 40% from 2010 levels.

However, cycles in budgets are not new to the DoD. In order to understand and mitigate the impacts to programs from changes in the industrial base and vice versa, the DoD published a Directive with a handbook in 1996 formalizing the assessment of defense industrial capabilities on a case-by-case basis (DoDD 5000.60H, 1996). Once an area of concern is identified, the handbook provides a framework to determine the need for government action to preserve industrial capabilities vital to national security. The framework is useful, but reactive and program-centric.

The current period of lower DoD acquisition spending is expected to place stress on the industrial base, particularly those parts that are dependent on defense spending. Budget cuts result in reduced levels of procurement for a program, delays in starting new programs, and cancelation of existing programs. While primes manage their individual supply chains effectively, the *cumulative effect* of multiple program procurement decisions can have unintended consequences on vital capabilities. Accordingly, the DoD requires proactive insight into the impacts of acquisition decisions made today on the industrial capabilities it requires now and in the future. Building on the existing framework, the Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy (ODASD[MIBP]) developed a methodology that could be used proactively, across Services and industrial sectors, that is rigorous, repeatable, and transparent. This paper describes the results of a pilot effort conducted through summer 2013, the methodology, and next steps.

Budget Cycles and the Department of Defense

Defense investment outlays, including funding for procurement and research, development, test and evaluation (RDT&E), have been cyclic since at least World War II (see Figure 1). Budget swings have significant consequences for the industrial base as they try to make business decisions around the volatility. During the upswings, defense contractors and their vendors must acquire resources, which are sometimes limited and specialized, to address their schedule and performance requirements. During the downswings, those same contractors must look into their crystal balls and make strategic decisions on how much of that capability they can afford to maintain in anticipation of the next upswing, or decide that the risk is not worth the reward and exit the defense market.

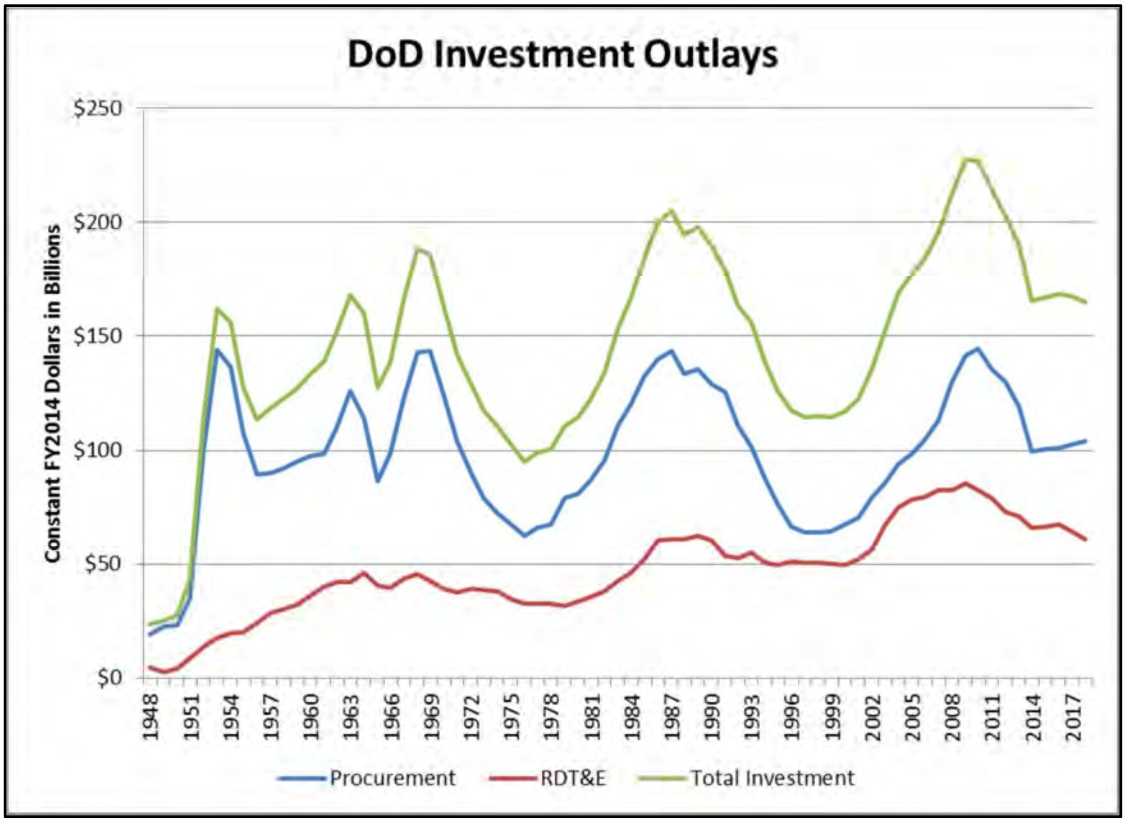


Figure 1. DoD Investment Outlays, 1948–2017, Constant 2014 Dollars
(Source: National Defense Budget Estimates for FY 2014, May 2014, Tables 6–11)

Research suggests that DoD budget upswings have very limited effects on technological advances despite the influx of dollars (Mowery, 2013). Instead investments in research and innovation during mobilization focus on bringing near-term, largely incremental technology to the solider. As a result, investment decisions made during downswings are vitally important to ensuring that the industrial base that supports the DoD will be able to provide the capabilities needed at the right time and quantity to maintain superiority over adversaries.

Reduced DoD procurement affects prime vendor decisions on how to absorb cuts, and their decisions flow down to the sub-tier suppliers. The fundamental questions from an industrial base perspective in deciding what and where to make cuts are: Will a capability that is needed to support the warfighter be available during a downturn and at the next upturn? Will the industrial base support the next generation of innovation?

Characterizing Risk in the Defense Industrial Base

The DoD faces two kinds of risk in the industrial base—voluntary and involuntary. Involuntary risk is incurred from external influences such as the Defense procurement budget, congressional mandates, and emerging national security threats. Each of these influences impact DoD decisions on amount and type of activity that is distributed among the predominant factors of research and development, acquisition, and sustainment.

Voluntary risk arises from the consequences of decisions within the Department's sphere of influence. This includes decisions about when and how the Department will rely on market forces to create, shape, and sustain industrial and technological capabilities, as

well as how it will intervene when absolutely necessary to create or sustain essential industrial capabilities.

During the Korean War, DoD investment outlays comprised over 5% of total gross domestic product (GDP), sustaining a strong symbiotic relationship with U.S. industry of earlier eras. The influence of defense investment outlays has dropped since the late 1980s to less than 2% of GDP, with a concentration of certain industries, globalization of markets, and increased export markets. The simple fact of having a private sector industrial base, frequently international, that is largely outside of the DoD's control reduces the Departments options for risk mitigation. However, that limitation is only a minor deterrent to action.

Before we can implement any mitigation actions, we must first identify the action as a solution to a known industrial base deficiency. Before an industrial base deficiency can be known, we must be able to compare defense requirements to industrial base capabilities. Before we can compare industrial base capabilities to requirements, we must have visibility into capabilities of individual product and service providers and their supplier networks.

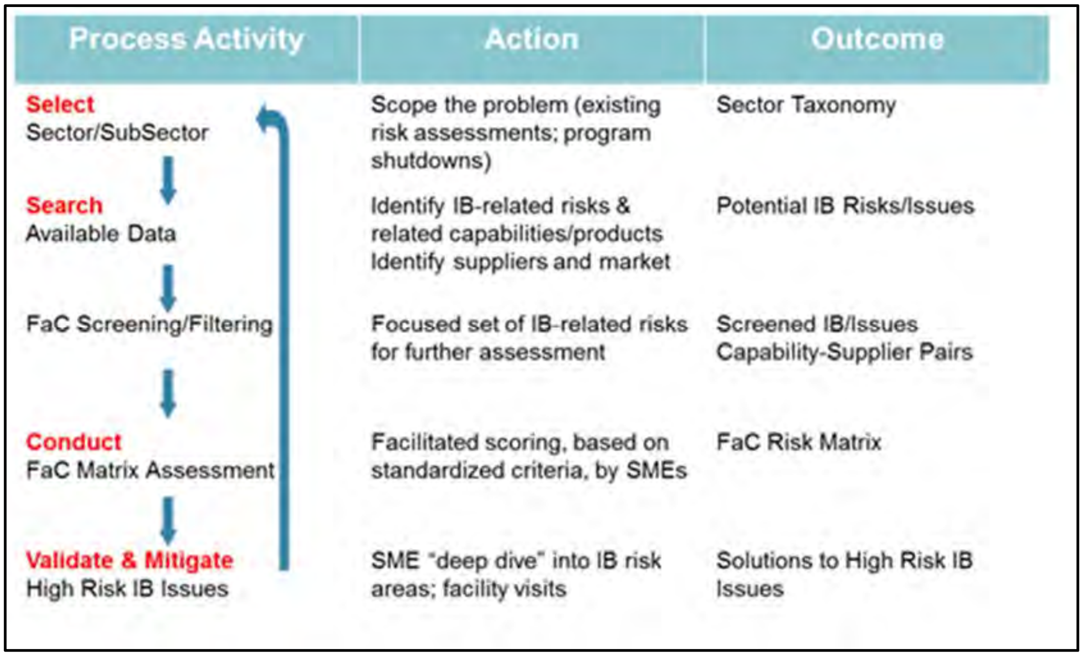
In 2008, the Government Accountability Office reported that the DoD's efforts to monitor its supplier base lacked a Department-wide framework and consistent approach. The report noted that DoD monitoring efforts generally respond to individual program supplier-base concerns or are broader assessments of selected sectors; use an informal approach to identify supplier-base concerns, often relying on the Military Services, program offices, or prime contractors to identify and report these concerns, including gaps or potential gaps; and, since no requirement for when to report such gaps to higher-level offices exist, knowledge of defense supplier-base gaps across the DoD may be limited.

In 2011, ODASD(MIBP) was tasked with developing a forward-leaning approach that could identify the cumulative effect on vital capabilities of procurement decisions across programs and Services. We built on the existing 1996 framework to develop a methodology that could be used proactively, across Services and industrial sectors, that is rigorous, repeatable, and transparent. The process became known as the Sector-by-sector, Tier-by-tier Fragility and Criticality (FaC) assessment process, or FaC for short.

Methodology

The DoD tested the FAC Assessment Process by completing 10 pilot FAC assessments in 2013 that included a mix of sectors (space, missiles, military satellite communications terminals, and focal plane arrays), programs (WIN-T Inc.1, F-18, F-22, Gray Eagle), and skill areas (organic depot, vertical lift). From these pilots, the DoD refined the process and the resulting high-level overview, presented in Figure 2. The process is designed to be iterative and provide continuous expansion of the DoD's insight into industrial base capabilities and constraints.

The first activity in the FaC assessment process is to *select the assessment subject and scope.* The assessment generally begins by choosing an industrial base sector or subsector within that sector. However, as additional insight is acquired, future iterations may focus on more limited technology or commodity areas. Selection of a program or sector for a FaC assessment is based on leadership priorities, industrial base analysis, and the results of prior industrial base assessments.



Process Activity	Action	Outcome
Select Sector/SubSector	Scope the problem (existing risk assessments; program shutdowns)	Sector Taxonomy
Search Available Data	Identify IB-related risks & related capabilities/products Identify suppliers and market	Potential IB Risks/Issues
FaC Screening/Filtering	Focused set of IB-related risks for further assessment	Screened IB/Issues Capability-Supplier Pairs
Conduct FaC Matrix Assessment	Facilitated scoring, based on standardized criteria, by SMEs	FaC Risk Matrix
Validate & Mitigate High Risk IB Issues	SME "deep dive" into IB risk areas; facility visits	Solutions to High Risk IB Issues

Figure 2. FaC Assessment Activities, Actions, and Outcomes

A functional- or component-based taxonomy of the sector is used to scope the FaC Assessment, indicating the focus (and non-focus) of the assessment. Sectors, subsectors, and programs intersect in a number of ways, and the taxonomy provides the "boundary" for what is in or out of scope for a particular assessment and highlights where future efforts might focus. The FaC is designed as an iterative process, and the taxonomy is instrumental to identify the sub-tier markets that comprise the sector, and to decide when to go broader or deeper in a subsequent iteration. A preliminary schedule and initial analysis prepares the working group members on their role and expected assessment outcomes. This helps to identify functional areas that may also impact other sectors, allowing for data re-use.

A key element of the process is to create the FaC Integrated Product Team (IPT). The IPT is a mature and well-established mechanism for having cross-organizational and cross-disciplinary dialog about an issue area. A FaC sponsor determines when there is sufficient justification to proceed with a FaC assessment, and acts as, or identifies, a FaC IPT chair. The chair is responsible for establishing the IPT, setting and overseeing the FaC assessment. The IPT chair hosts a kickoff meeting where the IPT members are briefed on the selected sector and the information collected to date. The IPT members are trained on the FaC assessment process to make sure that the results of this assessment are consistent with other assessments being conducted by other groups. Due to the iterative nature of the FaC, the IPT must be equally flexible to ensure that the requisite expertise is available for the assessment.

The second activity in the process is to *search for data and filter out non-industrial base issues* to support industrial base assessment. In today's resource constrained environment, the analyst cannot afford to conduct an open, unbounded search for information. Once the assessment scope is selected, industrial base analysts will evaluate available data sources for potential inclusion in the FaC assessment. Specific program or sector and supplier information included in existing databases, tools, programs, etc. is identified through the FaC criteria lens. Care is taken to ensure a transparent link to all data sources, and to share data sources among the FaC assessments. When the analyst finds deficiencies in the available information, they may contact subject matter experts (SMEs)

knowledgeable in relevant technologies or the acquisition supply chain to augment the knowledge base.

A DoD platform can have thousands of parts and associated vendors and an industrial base sector has even more—so many that it would be impractical to evaluate all of them in any single assessment. Accordingly, before conducting a FaC assessment, the IPT applies a set of filters to arrive at the target set of capabilities and vendors. The filtering activity is essential to the FaC process: filtering rids the assessment of non-industrial base issues, and it protects against data overload by focusing the efforts of the IPT on areas of higher probability of risk.

While some filters were used in each IPT, each IPT also chose additional filters tailored to the sector or program under investigation. Since the focus of the assessment is to identify risks in the defense industrial base, a crucial task is to weed out risks that, while important, are not important to the industrial base. Specifically, program-related supply chain issues do not necessarily impact the industrial base. Accordingly, one of the screens applied to each capability is whether it is relevant to many platforms and Services. If the answer is no, there may be risk in the supply chain for the capability, but it is not considered a risk in the industrial base since mitigation efforts are appropriately handled by the prime vendor or program office affected by the issue.

A primary objective of the FaC pilots was to achieve consistent application of industrial base assessment techniques across the assessment teams. To that end, the assessment community developed a FaC Assessment Candidates List (FAC-List). The FAC-List is a standard template used to collect the product and supplier identification information and record filtering decisions. While the FAC-List template contains default filters, each FaC IPT is able to add other filters as deemed appropriate. Some filters apply to all FaC's, for example, identifying capabilities associated with single sources of supply, while others are specific to the sector under investigation. The maturity of a capability may have a significant impact on the types of filters. A product or technology in development focuses more on attributes of new product or service technologies and prototype integration, while established products and technologies may focus on issues of obsolescence.

The result of the data collection and filtering activity is a winnowed down set of "capability and supplier" pairs that are moved forward for the formal FaC assessment. In the assessments, a capability required from the industrial base is defined as a technology, part, component or product. A supplier is defined as the current provider(s) of that capability. A capability, then, might be as small as an individual part or as large as an integrated subcomponent, each capability then paired with its current suppliers, and each capability/supplier pair assessed separately. Accordingly, the same capability may be associated with multiple suppliers, and a single supplier may be associated with multiple capabilities.

The third activity is to *conduct the FaC assessment*. The heart of the assessment process is the set of criticality and fragility criteria that serves as indicators of potential industrial base-related risk. Criticality, from an industrial base perspective, consists of indicators to identify when a capability would be difficult to replace if it was lost or disrupted. Fragility indicators focus on the robustness of current suppliers of a capability and the availability of potential firms in the current marketplace. Table 1 shows the criticality and fragility factors that the DoD initially selected for the pilot assessments.

Table 1. Fragility and Criticality Factors During 2013 Pilot Testing

Criticality: Characteristics that make a specific *Capability* difficult to replace if disrupted (Capability = technology, part, component, product	
Defense unique capability	To what degree is the market for this capability commercial?
Relevance to DoD	How pervasive is this capability across the DoD?
Skilled labor requirements for the capability	To what degree are specialized skills needed and available to integrate, manufacture or maintain this capability?
Design-intensive activity	To what degree is defense-specific knowledge required to reproduce this capability, an alternative, or the next generation design?
Level of future demand	What is the expected global, commercial, military, and other government demand over the next 5 years?
Reconstitution cost	What is the impact on the DoD to restore this capability if it is lost?
Availability of alternatives	To what degree are cost, time, and performance-effective alternatives available to meet DoD needs?
Geo-political climate	Where is the market for this capability and what is the degree of foreign dependency in terms of alternative suppliers?
Long lead item	What is the impact on the DoD from the lead time to obtain the capability from the current market?
Fragility: Characteristics that make a specific *Capability* likely to be disrupted (Will the Department receive what it needs, when it needs it?)	
Financial outlook (Current provider)	What is the risk of this facility going out of business or exiting the market for this capability?
DoD dependence (Current provider)	What percentage of total sales for this facility are from DoD contracts?
Firms in sector (Existing market)	How many firms currently participate in this firm’s market for this capability?
Impact on firms cost from variation in output	What is the estimated impact from a 50% change in DoD procurement on the unit cost?
Production minimum sustaining rate	What are the production levels of the firm relative to MSR?
Diversity of firm’s earnings from program elements	How many distinct programs, products, or service groups create revenue for the firm?

The information required to assess FaC criteria in combination with demographic and economic data of the commercial organizations permits industrial base analysts to sort risks based on whether a given risk is rooted in broad industrial base issues or is unique to a particular capability. Armed with the filtered list of target capabilities to assess, the IPT members hold an assessment workshop to complete a FaC assessment using the fragility and criticality assessment criteria and rating scales. During the workshop, SMEs evaluate the criticality and fragility factors for each capability. This assessment process leads to a FaC Assessment Risk Matrix, identifying the most critical capabilities and fragile suppliers. The high-risk capabilities become the subject for further investigation and validation. SME recommendations for areas that require further investigation, along with any risk mitigation suggestions, are some of the workshop results and a basis for follow-up actions.

In the pilot phase, a facilitator guided the in-person SME’s through the scoring exercise. The IPT members first assessed each capability, assigning a score on a 5-point scale for each criticality measure. When SME’s were unanimous on a rating, the score was recorded on the matrix. When SME’s differed, a discussion ensued, with comments captured. Often the SME’s agreed on a rating after sufficient dialogue. However, when an agreement could not be achieved, the more conservative, higher risk rating was recorded

and duly commented, and the process continued to the next factor, and so on, until each factor and capability was assessed. After rating each capability, the unweighted scores were averaged and plotted on a 5-point scale. As the pilots progressed, the FaC assessments began to focus on the capabilities with the highest criticality ratings before scoring fragility based on the assumption that if a capability was not critical from an industrial point perspective, there was (relatively) less concern over the market for the capability.

After establishing the criticality ratings for each capability, the IPT members focused on the fragility factors. The process for rating and recording each factor was the same as described above, except SME's now focused on aspects of the market for a capability. Scoring of the fragility factors turned out to be problematic for a number of reasons. First, the IPT members who had deep knowledge about the capabilities required by the DoD, were less likely to know financial or other details about a specific firm. As discussed in the Results section, adjustments made to the fragility measures during the course of the pilots improved the robustness of this indicator, which will be tested as part of the 2014 FaC assessments.

When the IPT completes the individual scores, the next step in the pilot was to elicit weights. The discussion and application of weights by the SMEs was important to gain insight into what the IPT believed to be important determinants, to test the patterns across the 10 pilots, and to establish the impact of weighting on the outcome.

The fourth activity is to *validate high-risk industrial issues and develop mitigation strategies.* Figure 3 presents a visual example of a final FaC Assessment Risk Matrix generated by the pilots. The dots representing capability/supplier pairs in the upper right quadrant of the chart are capabilities that represent potential risks to the DoD in the industrial base. The scoring allows IPT members to focus on the highest risk (red-orange) items as the most critical and fragile elements, which are also mapped back onto the taxonomy to reveal whether specific subcomponents contain multiple risks.

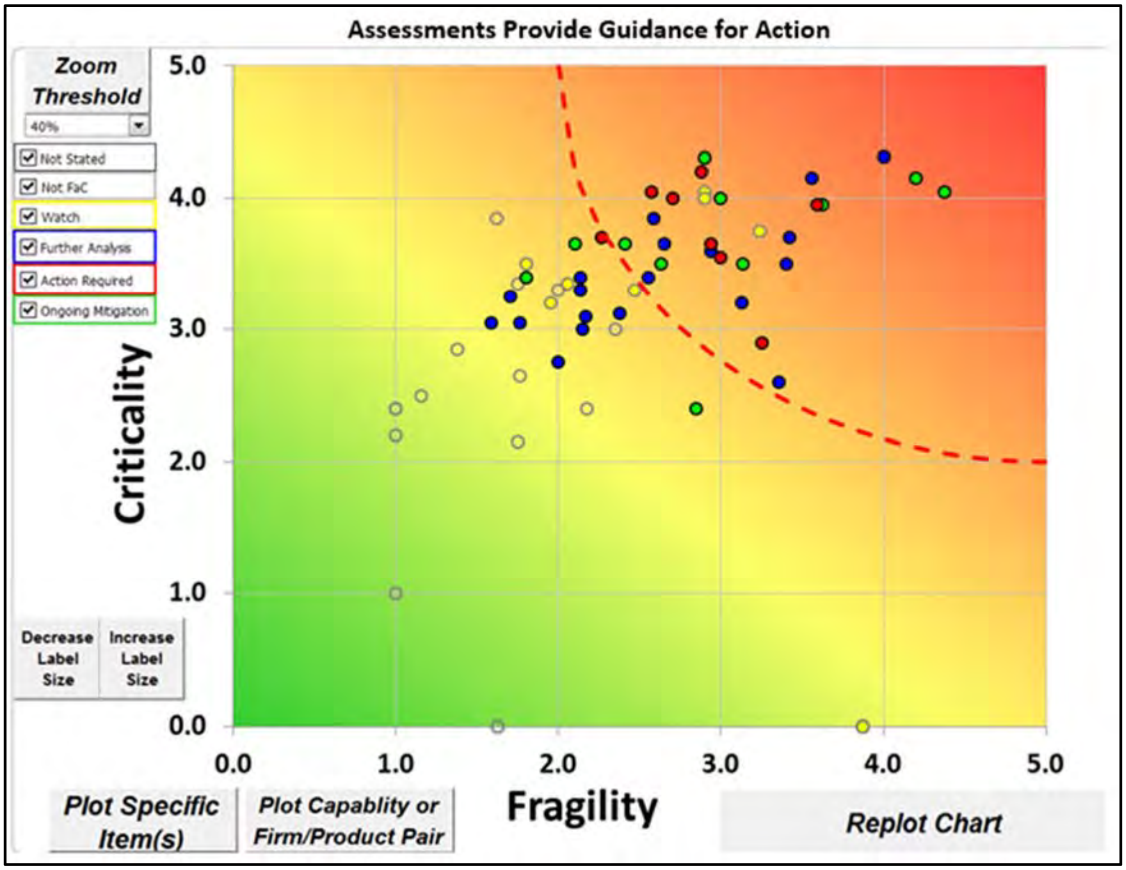


Figure 3. Fragility and Criticality Risk Matrix

The FaC assessment process is intended to be a rapid filter that allows more efficient focusing of resources on the highest risk areas. Accordingly, the IPT can now focus their efforts on validating a few dozen capabilities in a sector to determine which ones require further analysis, continued observation, or immediate mitigation. The findings and recommendations are presented to leadership on possible mitigation strategies.

The fourth activity brings closure to the preceding three activities and sets the agenda for a subsequent iteration of the FaC analysis, if required. A subsequent iteration could involve selecting a different part of a sector/subsector, modifying the membership of the IPT to be able to dig deeper into the sector under investigation.

FaC Results

The goal of the FaC assessment pilots was to test a DoD-wide methodology that could be used proactively, across Services and industrial sectors, that is rigorous, repeatable, and transparent. After scoping the area of interest through use of a sector taxonomy, the process includes a structured approach to rapidly sift through information to focus on potential industrial base-related issues, followed by a facilitated scoring by subject matter experts based on defined criteria. The outcome yields a manageable set of issues for mitigation. In practice, the pilots provide much evidence to support the goals, as well as areas of the process that require modification.

One of the most salient results that emerged from the FaC pilots is the need to focus on non-program assessments. An early assumption was that FaC assessments should be conducted program-by-program to build a systematic understanding of industrial base

issues, and the assessments would provide input into program-level budgeting. Four of the assessments were conducted at the program level. However, program managers are skilled at managing risks in their respective supply chains, and limited new information was gleaned from program-level FaC assessment. On the other hand, the FaC pilots conducted at sector levels yielded significant and new information about potential risks across multiple programs. Indeed, even in heavily studied sectors such as space or missiles, the process helped to identify new risks, as well as point the way to potential mitigation based on the characteristics of the risks. The challenge with presenting risk at a cross-program and cross-Service level is that budgeting occurs in program silos. Accordingly, results of the 2013 FaC pilots were taken to a Deputy's Management Action Group[1] on the Industrial Base in December to determine how to resource the mitigation actions.

In response to feedback from the IPT teams, we developed several tools to facilitate the FaC process. As mentioned above, a structured FaC-List helped to capture data and comments, and the filters used for each pilot. The process of filtering industrial base-related issues evolved over the first several FaC pilots, and these lessons learned were incorporated into subsequent pilots. The FaC Assessment Results Matrix is a set of macro-enabled worksheets that translate the individual scores onto a traditional risk matrix. The tool allows the IPT members to visualize the results in real time, facilitating discussion of the outcomes, and also allows members to do various "what if" scenarios based on changes to underlying assumptions.

A key result of the pilots is validation of the criteria and overall assessment results based on SME knowledge. At the conclusion of each FaC assessment, the SME's were asked to step back and evaluate whether items identified as high risk, were indeed high risk, and conversely, if those items rated as low risk, were low risk. There were no cases of a false high risk identified. In a few cases, an IPT member would articulate a low risk item should be rated higher. The team would reevaluate the ratings relative to the definitions, and the facilitator would inquire about other factors that might be missing. The activity sometimes resulted in a higher rating for a capability, which then had to go through the rigorous validation process. As a rule, though, the SME's agreed with the aggregate ratings and rankings, which was viewed as an important outcome of the pilot effort.

The area requiring the most review is the factor rating definitions. The initial 5-point rating scale was designed as a continuum of low to high impact for a particular factor. During the pilots, IPT members expressed concern around some of the scales that didn't reflect their sector. For example, the original scale for "Long Lead Time" was anchored on actual lead times, with greater than two years posing significant risk. However, the IPT for some sectors indicated that lead times of three or more years were common, and programs factored these into their planning. As such, the fixed scale did not reflect the *impact of lead time*. In another example, the factor for "Geo-political climate" was used as both a criticality and a fragility factor under the assumption that items with only foreign sources of supply may exhibit risk not elsewhere captured. Half of the pilots included a modified factor reflecting this concern as a fragility indicator. The pilots also revealed that the firm-level

[1] The Deputy's Management Action Group (DMAG) serves as the Defense Business Systems Management Committee (DBSMC), which is a joint committee of senior leaders responsible for executing a common approach across Departmental processes.

information was not available on a consistent level except for financial stability, rendering some indicators largely unused.

Despite the difficulties with the rating scales, like any good pilot testing, the subsequent IPT's continued to improve as the definitions became sharper and easier to use. We conducted a series of empirical and statistical analyses of the collective ratings to further understand the results of the pilots.

Empirical Evidence From Pilot Tests: A repeatable process requires repeatable results under a variety of settings. The 10 pilot assessments were conducted at different levels of analysis—program, sectors, and integrated components. The question thus arises—does the rating structure hold up under any level of analysis? The pilots were designed to elicit weighting between factors to understand a number of questions, including, for example, whether the maturity of an industry segment influenced the importance of some factors over others. Consequently, how do results change when weights from one pilot are applied to others? Finally, the fragility factors were particularly challenging to rate, and evolved over the course of the pilot tests. What is the impact on the rankings of early pilots when certain fragility factors are excluded from the assessment?

During the FaC process, each IPT validated the rankings and results of their assessments. We used this observation to establish internal validity of an assessment since the SMEs were satisfied that the resulting risk matrix accurately portrayed the relative intensity and rank order of industrial base risks within their areas of expertise. This fundamental assumption was then used to test various constructs. The first step was to understand the impact of various weighting schema on outcomes.

At the conclusion of the rating of each criticality and fragility measure, the results were displayed on the risk matrix based on equal weighting of each measure. Our *a priori* assumption was that each measure did not contribute equally, yet we lacked the data to assign unequal weights. Thus, one of the tasks of the IPT facilitator was to elicit weights within pilot FaC. The facilitator returned to the list of criticality measures and asked a series of questions aimed at determining which single indicator was most important, recording the responses of various SMEs. Then, which two or more measures were most important, and so on. In each pilot, the same four criticality indicators were ranked as most important to overall criticality rating: defense unique, relevance to the DoD, availability of alternatives, and reconstitution cost. Labor skills and design intensity were consistently ranked next highest in importance. Future demand, geo-politics, and lead times were ranked lowest or received zero weighting. Although IPTs might assign different actual weights to a measure, the overall consistency of which factors were most important provided insight and allowed us to test for stability in the results across the pilots.

Weighting the measures of fragility posed some challenges. As mentioned earlier, the SME's did not have insight into the level of detail required of some fragility measures for specific suppliers. Indeed, information on minimum sustainment rates or product-cost changes requires intimate knowledge of a supplier and, further, the data can grow stale more rapidly than other indicators. Accordingly, some IPT's chose to ignore these measures. In addition, early in the pilots, one of the IPT's chose to include "foreign dependence" as a fragility indicator, with the presence of only foreign sources as a high risk and two or more domestic sources as a low risk. Feedback from other SMEs spurred us to include the indicator in subsequent pilots, and to add the measure into completed FaC pilots. Not surprisingly perhaps, when weights were elicited for fragility measures, four indicators were highly ranked and the remaining indicators were a distant second or not weighted. The four fragility measures were: financial stability of the firm, DoD dependence of the firm, number

of firms producing in the market, and foreign market dependency. As with the criticality measures, the observed regularity across the pilots of a core set of fragility indicators provided understanding of the process.

The FaC-Matrix tool was designed to allow real-time changes of the weights for each measure to test the impact of the weights within each pilot. The second empirical step was to combine together like assessments—programs with other programs, sectors with other sectors—to observe for anomalies in the ratings. Including the nine criticality measures and four fragility measures described above, the result of this exercise revealed that all risk rankings in the combined assessments remained stable. The final step was to combine all assessments into a single FaC matrix to observe for differences across the different levels of analysis—program or sectors. Again, the ratings in the combined assessments remained stable. We found no instances where items rated as high risk would fall out of the upper quadrant, nor low risk items rise into the higher quadrant.

Statistical Factor Analysis of Criticality Factors From Pilot Tests: Armed with evidence of consistency across the pilot FaC assessments, we next performed an exploratory factor analysis of the criticality measures. The goal of such analysis is to reduce the number of dimensions—in this case, criticality attributes—by grouping them into factors that vary together in a statistically meaningful fashion (Gorsuch, 1997). The dimension reduction aids in narrowing the search for meaningful measures by identifying which attributes make significant contributions to the variance of the data set.

As indicated above, the pilot study data on the fragility indicators held up under empirical testing, but changes over the course of the pilots yield only small sets of data for factor analysis. However, data collected on the nine criticality attributes were consistent across the pilots. The data were diverse in that they were drawn from subcomponents, broad defense industrial sectors, and from individual programs in various stages of acquisition or sustainment. Criticality data collected from the pilot studies were subjected to a principal axis factor analysis to determine which of the attributes made significant contribution to the observed data variance. A total of 138 unique and complete responses gathered from the pilot projects were available for analysis.

Factor Extraction. The data were processed with an iMac running SPSS Version 21 for the OS X operating system. A dimension reduction was performed on the data set using principal axis factoring. Table 2 is a breakdown of the extracted factors and the corresponding variance explained by each factor.

Table 2. Total Variance Explained

Factor	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	2.753	30.587	30.587
2	1.393	15.482	46.069
3	1.110	12.330	58.399
4	.988	10.972	69.372
5	.796	8.841	78.213
6	.676	7.506	85.719
7	.466	5.181	90.901
8	.447	4.970	95.871
9	.372	4.129	100.000

As presented in the top row, the first factor accounts for about 30% of the variance, with almost 60% of the variance in the data set explained by factors 1, 2, and 3, indicating that the nine criticality attributes (not to be confused with the nine factors extracted by the

analysis) could potentially be grouped into independent factors, with each factor defined by a unifying theme. The strongest three factors were retained for further analysis, based on their relative strength and the linear decrease in contribution of the remaining three factors.

The factor solutions were rotated using a Direct Oblimin transformation and loadings tabulated. Tables 3 and 4 are the resulting structure and factor correlation matrices, respectively. As presented in the second column of Table 3, four criticality measures make up Factor 1, as demonstrated by absolute value levels of greater than 0.4: Defense unique, labor skills, design intensity, and reconstitution cost. Factor 2 is driven by a single criticality attribute: availability of alternative capabilities, which is also cross-loaded with Factor 1. Factor 3 has three of the criticality attributes loading at greater than the 0.4 level with the almost all possessing a negative polarity. All three factors display independence and high orthogonality as illustrated by the low correlation values in Table 4.

Table 3. Structure Matrix

Criticality Attribute	Factor		
	1	2	3
Defense Unique	.787	-.122	-.112
Relevance to DoD	-.297	.322	.002
Labor Skills	.668	.028	-.306
Design Intensity	.663	.209	-.438
Available Alternatives	.319	.768	-.266
Future Demand	.323	.103	-.050
Geo-Political Climate	-.004	.185	-.005
Reconstitution Cost	.447	.249	-.664
Lead Time	.075	.017	-.660

Extraction Method: Principal Axis Factoring. Rotation: Oblimin with Kaiser Normalization.

Table 4. Factor Correlation Matrix

Factor	1	2	3
1	1.000		
2	.043	1.000	
3	-.250	-.145	1.000

The exploratory nature of factor analysis calls for a certain level of interpretation. It is expected that candidate attributes and constructs will not contribute to explaining the observed variance in the data. The dimension reduction and interpretation by the researcher are tools to focus on the attributes that best explain the behavior of the collected data.

The components of Factor 1 display a unifying theme of *niche capabilities*. A combined high risk rating would describe a capability that has low commercial applicability, requires highly skilled labor, demands deep design knowledge to produce an alternative, and would have a high impact on the DoD to restore the capability if it were lost. Factor 2, as a single indicator, does not require reinterpretation, but when viewed through the lens of the first factor, the combined theme suggests characteristics that make a specific product difficult to replace if disrupted, which is the description we employed to describe critical capabilities in the industrial base. The third factor is harder to interpret since criticality measures were not reverse-coded and, as noted, the loadings possess a negative polarity. Two of the three measures are included in Factor 1. Feedback received during the pilots suggested that the scale for Lead Time was not effective to capture the impact of long lead times on a capability. Based on the coherence of Factors 1 and 2, and uncertainty about the interpretation of Factor 3, we conducted a Cronbach's Alpha statistic to assess the reliability of the construct of Factors 1 and 2. The reliability statistic of 0.74 based on five items, and

significant item-total statistics provided confidence that we could reduce the number of Criticality measures from nine to five.

Analysis Conclusions: We conducted empirical tests on the combined pilot data using the five criticality measures and four fragility measures. While individual scores varied from the original scores, the resulting FaC Risk Matrix was unchanged with respect to the items identified as low risk, moderate risk, and high risk. Indeed, the reduced number of indicators provided more separation among the items, that is, there was less “clumping” of capability/supplier pairs with the removal of non-differentiating information.

From the data explorations and statistical analysis, we determined that Criticality as a construct is measuring those capabilities that are difficult to replace if lost. Feedback during the pilot FaCs indicated that the measure for “reconstitution cost” was a proxy for other factors, including a missing variable related to the cost of facility and equipment to produce a capability. In addition “cost” was not precise indicator for the measure; instead the IPT teams assessed the impact on the DoD in the amount of *time to restore* the capability if it was lost. Building on these findings, we tightened the definitions of criticality and fragility ratings as presented in Table 5 and included a sixth measure of criticality to account for facility and equipment requirements.

Table 5. Revised Fragility and Criticality Factors for 2014 Assessments

Criticality: Characteristics that make a specific *Capability* difficult to replace if disrupted (Capability = technology, part, component, product	
Defense unique capability	To what degree is the market for this capability commercial?
Skilled labor requirements for the capability	To what degree are specialized skills needed and available to integrate, manufacture or maintain this capability?
Defense design requirements	To what degree is defense-specific knowledge required to reproduce this capability, an alternative, or the next generation design?
Facility & equipment requirements	Are specialized equipment or facilities needed to integrate, manufacture, or maintain this capability?
Reconstitution time for the capability	What is the impact on the DoD in time to restore this capability if it is lost?
Availability of alternatives	To what degree are cost, time, and performance-effective alternatives available to meet DoD needs?
Fragility: Characteristics that make a specific *Capability* likely to be disrupted (Will the Department receive what it needs, when it needs it?)	
Financial outlook (Current provider)	What is the risk of this facility going out of business or exiting the market for this capability?
DoD sales (Current provider)	How much total sales for this facility are from DoD contracts?
Firms in sector (Existing market)	How many firms currently participate in this firm’s market for this capability?
Foreign dependency (Existing market)	What is the dependence on foreign sources for this capability?

Next Steps

The 10 FaC pilot assessments completed in 2013 identified important risks in the industrial base and provided actionable mitigation strategies to DoD leadership. The pilots also provided lessons on how to improve the overall FaC process, reduce ambiguity in definitions, and provided empirical and statistical evidence to improve the constructs for criticality and fragility. In 2014, we will continue to refine the process during the next round of

assessments. Although we expect these assessments to be much improved as we reflect on the lessons learned, the process is not yet fully unified and consistent. As we proceed with the 2014 list of sectors, subsectors, and systems, we will also be pursuing the following process improvement activities:

- **Access to Data:** The 2013 assessment teams were often unable to locate consistent data about some of the factors, particularly for fragility measures. Thus, the initial evaluation was determined by SME experience or group opinion, and subsequently validated if the capability was both fragile and critical. In 2014, MIBP will enhance its ability to acquire reliable data by expanding its access to data, including fee-for-service sources, refining its use of selective survey instruments, and acquiring analysis tools that improve the ability to assemble, evaluate, and visualize industrial base information.
- **Expanded Use of Taxonomies:** A taxonomy for each FaC assessment is essential to the process. The taxonomy provides a scoping mechanism on the front end, a guide during mitigation, and a map for future iterations. In 2013, the taxonomy was not always used throughout the entire FaC process. In 2014, MIBP will work to standardize the taxonomy format, and to incorporate more explicitly the taxonomy into each activity in the FaC.
- **Standardized Filters:** The FaC assessment is a process to quickly isolate the risks in the industrial base to the delivery of materiel to support the warfighter. The 2013 pilots were completed in six months or less. Our aim is to complete FaC's in half that time to be proactive in identifying emerging issues, and agile in responding to existing ones. To achieve this goal, we need to institute guides for prioritizing the capabilities that are taken forward to the FaC Matrix scoring session. The pilots provided valuable insight into the filters that can help triage the issues. In 2014, we will refine and categorize the filters to reduce the amount of time devoted to this activity.
- **Evaluation of Technology Gaps:** Returning to the definition of criticality, FaC assessments identify specific capabilities that are difficult to replace if disrupted. We believe there is an opportunity to contribute to the body of knowledge of how to evaluate the link between defense procurement and the industrial base. In short, we envision risk identified through FaC as a "gap" between Defense and commercial capabilities—if robust commercial demand exists, then the capability should be relatively easy to replace even when Defense procurement investments decline. While there are many benefits to overlapping Defense and commercial capabilities (e.g., no gap), there are drawbacks as well. A gap between Defense and commercial capabilities can be good for national security, for example, when the Warfighter is equipped with capabilities that are not available to our adversaries. In 2014, we will use our FaC assessments to explicitly examine the issue of which gaps provide benefits to the Department, and which ones create unnecessary risks.

Closing Comments

> The cascading effects on [small, highly specialized companies] of decisions that the Department makes at the overall programmatic level must be better understood—to ensure that critical lower-tier providers have the capacity to respond to these decisions, to ensure the continued supply of critical subcomponents to our defense industrial base, to ensure that critical skills

> are not lost, and to protect our national security from the risk of using compromised supply chains. (2010 Quadrennial Defense Review, p. 82)

Budget cycles are not going away. ODASD(MIBP) has made significant headway into instituting a rigorous, repeatable, and transparent process to identify and mitigate the impact of DoD investment decisions on the industrial base. The pilot tests served to refine and improve the process, and provided defensible results used to inform budget decisions. The FaC methodology promotes a proactive industrial base perspective by not assuming away the industrial base, by conducting regular assessments of industrial base capability and risk, and then deciding explicitly when to accept industrial base risk and when to mitigate that risk. In other words we just don't want to let risk happen. Over the next several years, the iterative conduct of FaC assessments will provide the DoD with an improved understanding of the capability and risk dynamic. This, in turn, will help ensure that the Department can protect and support the Warfighter to the highest possible extent.

References

Defense Science Board (1981), *Report of the Defense Science Board: 1980 Summer Study Panel on Industrial Responsiveness*.

Defense Science Board (July 2008)., *Creating an Effective National Security Industrial Base for the 21st Century: An Action Plan to Address the Coming Crisis*, Report of the Defense Science Board Task Force on Defense Industrial Structure for Transformation.

Gorsuch, R. L. (1997). Exploratory factor analysis: Its role in item analysis. Journal of *Personality Assessment, 68*(3).

Mowery, David C., January 2013. *Public Procurement and Innovation in the post-1945 U.S. Economy*, Working Paper, Haas School of Business, University of California, Berkeley.

U.S. DoD (April 25, 1996), DoD Directive 5000.60-H, *Assessing Defense Industrial Capabilities.*

U.S. DoD, *Quadrennial Defense Review* (February 2010).

U.S. DoD, Office of the Under Secretary of Defense, Comptroller (May 2013), *National Defense Budget Estimates for FY 2014*.

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